Rail Accident Investigation Branch

Rail Accident Report

The blowback of a locomotive fire at Grosmont on the North Yorkshire Moors Railway 16 April 2006

Department for Transport

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This investigation was carried out in accordance with:

- the Railway Safety Directive 2004/49/EC;
- the Railways and Transport Safety Act 2003; and
- the Railways (Accident Investigation and Reporting) Regulations 2005.

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Introduction

1 The sole purpose of a Rail Accident Investigation Branch (RAIB) investigation is to prevent future accidents and incidents, and improve railway safety.

2 The RAIB does not establish blame, liability or carry out prosecutions.

3 Access was freely given by the North Yorkshire Moors Railway (NYMR) to its staff, data and records in connection with the investigation.

4 Appendices at the rear of this report contain Glossaries explaining the following:

- acronyms and abbreviations are explained in Appendix A; and
- technical terms (shown in *italics* the first time they appear in the report) are explained in Appendix B.

Summary

Key facts about the accident

5 At around 10:10 hrs on 16 April 2006, locomotive 75029, hauling the 09:45 hrs passenger service from Grosmont to Pickering on the North Yorkshire Moors Railway, suffered a blowback of its fire approximately 1160 m south of Grosmont station.

6 The blowback filled part of the *footplate* with flame for between 4 and 10 seconds. The locomotive driver suffered minor burns.

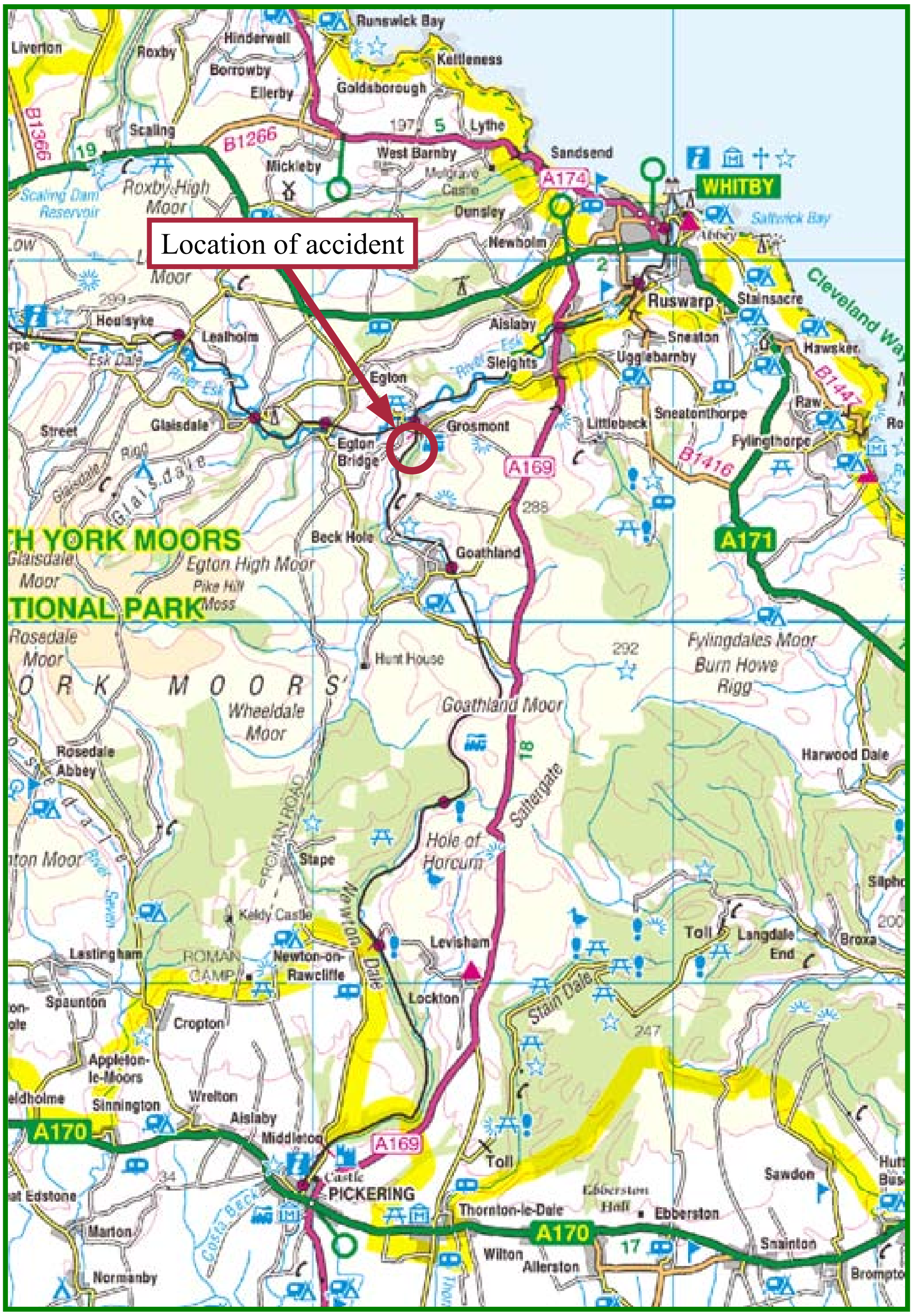


Figure 1: Extract from Ordnance Survey map showing location of accident

Immediate cause, contributory factors, underlying causes

7 The immediate cause of the accident was a loss of forward draught (from *firebox* to *smokebox*) at a time that the *firehole doors* were open.

8 The following causal factors were identified:

- a movement of the blastpipe led to a loss of smokebox vacuum;
- the locomotive was operating with a *blastpipe* base/*saddle plate* weld that had failed some time previously and had not been noticed and repaired.

9 In addition, the following factors were considered to be contributory:

- high exhaust pressure as a result of the control positions;
- the blastpipe base/saddle plate weld was likely to have been made undersized relative to the design drawing;
- the blastpipe base/saddle plate weld was subject to long-term corrosion and erosion;
- the condition of the weld was not easy to see;
- no party involved in the recent overhaul and its associated inspections specifically inspected the blastpipe base/saddle plate weld;
- the responsibility for mechanical inspection of the locomotive during overhaul and associated inspection and testing was not clearly defined;
- indicative signs prior to the incident did not lead to an examination of the blastpipe base/saddle plate weld by NYMR;
- the NYMR maintenance regime did not call for periodic inspection of the blastpipe base/saddle plate weld.

10 The following underlying causes were identified:

- The risk associated with the failure of the blastpipe base/saddle plate weld was not generally appreciated because such an incident had not occurred before and there was not a full understanding of the construction of the blastpipe base/saddle plate interface;
- NYMR maintains locomotives to procedures derived from universal British Railways (BR) steam locomotive standards, with problems experienced causing maintenance procedures to be modified. This means that a specific risk associated with a specific locomotive type that has not been known to have occurred previously, may not be controlled.

Severity of consequences

11 The driver of the locomotive suffered minor burns to the right hand and right hand side of the face.

12 The incident had the potential to have resulted in much more severe consequences, had anyone been standing in line with the firehole door.

Recommendations

13 Recommendations can be found in paragraph 112. They relate to the following areas:

- the inspection and repair of blastpipe base/saddle plate welds;
- the provision of an appropriately sized blastpipe base/saddle plate weld;
- defining the scope of any provision for mechanical inspections when outsourcing work;
- assessment of hazards to train crew and public in the development of maintenance schedules;
- provision of first aid kits on locomotive footplates;
- annealing of copper *blower feed pipes*;
- notification of incidents between the heritage sector and the mainline railway.

The Accident

Summary of the accident

14 At around 10:10 hrs on 16 April 2006, locomotive 75029, hauling the 09:45 hrs passenger service from Grosmont to Pickering on the North Yorkshire Moors Railway, suffered a blowback of its fire approximately 1160 metres south of Grosmont station.

15 The blowback filled part of the footplate with flame for between 4 and 10 seconds. The locomotive driver suffered minor burns.

The parties involved

16 The North Yorkshire Moors Historical Railway Trust is the owner of the 18 mile (29 km) stretch of preserved railway between Grosmont and Pickering. North Yorkshire Moors Railway Enterprises plc have operated the line since 1974.

17 All locomotives on the line are operated by NYMR, although many are owned by other companies or individuals.

18 *Riley & Son (Electromec) Ltd (Rileys)* are owners and maintainers of steam locomotives. They have traded under the current name since incorporation in 1997 and prior to that as 'Ian V. Riley' since 1989.

19 Steam Powered Services Limited (SPS) was formed in 1992 as a trading company selling a variety of engineering products and services. The articles of association include the provision for buying, restoring and operating railway equipment. Since formation, SPS have owned or leased four steam locomotives as well as other railway rolling stock.

20 Boiler Inspector A has been operating as an independent Boiler Inspector/Engineer Surveyor for the last 19 years and has worked on many types of steam locomotive boilers. The majority of Inspectors A's work comes from the heritage railway sector and includes examinations and audits for *Vehicle Acceptance Bodies* (VAB). In this instance Boiler Inspector A was conducting periodic boiler inspections on behalf of SPS.

21 Boiler Inspector B has been working as an Engineer Surveyor (pressure systems) since 1979 and is presently employed by Allianz Cornhill Engineering (ACE). Inspector B's work has included locomotive boilers since 1994. ACE were the boiler insurers employed by NYMR.

22 AEA Technology Rail (AEAT), now known as DeltaRail, is a large railway consultancy. They are a VAB and as such, certify vehicles, including steam locomotives, prior to their use on the main line railway.

23 The locomotive driver started work firing locomotives on NYMR in 1983, qualifying as a driver there in 1987. The driver has also been driving steam locomotives on another heritage railway since 1981 and firing there since 1975.

24 The fireman started work on NYMR in 2003, reaching the grade of 'passed cleaner', which qualifies staff to fire locomotives, in January 2005. The fireman had worked for 6 years on another heritage railway prior to working on NYMR.

25 The cleaner, who has been a steam locomotive driver on another railway over the last year, started working on NYMR in 2003, reaching the grade of cleaner in April 2005. At the time of the incident, the cleaner was on the footplate as part of training to become a fireman.

Location

26 The incident occurred approximately 1160 m south of Grosmont station in the Esk Valley. At this point, the line is rising steeply at a gradient of 1:49 towards Goathland Moor; the summit is a further 3 miles (4.8 km) south. The line is on an embankment and in open countryside. There is a row of cottages, known as 'Esk Valley Cottages', not far from the west side of the line. A simplified diagram of the train's route is shown in Figure 2.

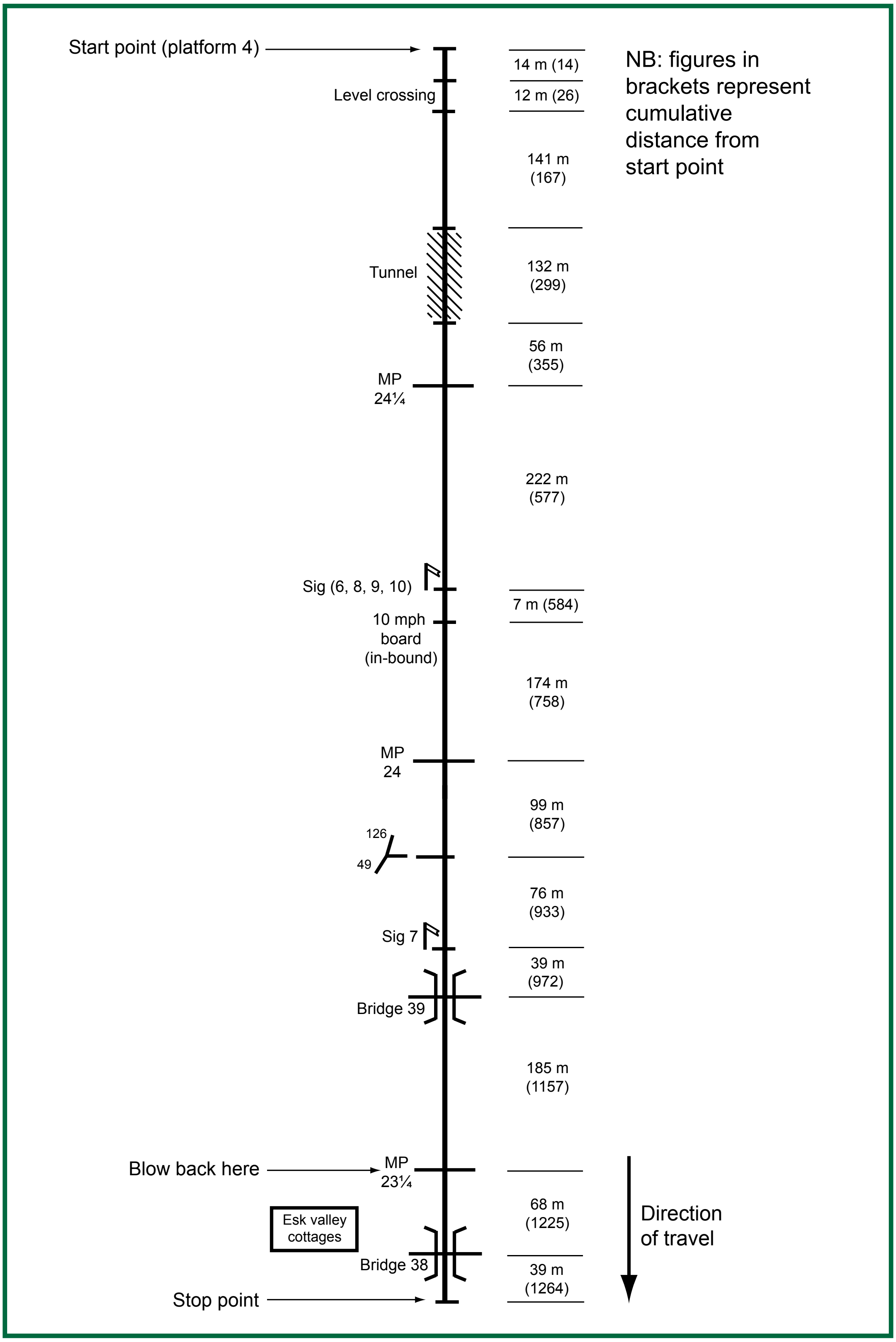


Figure 2: Simplified diagram of the train's route

The locomotive

27 Locomotive 75029, is a British Railways (BR) Standard Class 4, built in Swindon works. It entered operational service on BR in 1954. In 1957, it was fitted, experimentally at the time, with a double blastpipe and chimney. It was withdrawn from service on BR in 1967 and immediately purchased for preservation, spending time at various locations until it was withdrawn from service on the Great Central Railway (GCR) in 1997 requiring overhaul. The locomotive is pictured in Figure 3.

28 The locomotive was bought by SPS in 1998 with the intention that it be operated by NYMR on hire, once overhauled. The boiler was overhauled by GCR at Loughborough and the rest of the locomotive by SPS on NYMR property. On completion of this overhaul, 75029 entered service on NYMR in May 2000.

29 In November 2002, the locomotive was withdrawn from service requiring replacement tyres. It was sent to Rileys in Bury for new tyres and work on the firebox. However, as work progressed, more items that needed attention were revealed and it was decided to fully overhaul the boiler in order to obtain a new 10 year *boiler ticket* and carry out various mechanical works. The works necessitated the removal of the blastpipe from its base and its subsequent refitting. However, the blastpipe base was not required to be separated from the saddle plate.

30 On or around the time that the overhaul was completed in October 2005, the locomotive was inspected by:

- Boiler Inspector A, on behalf of the owner as part of the Pressure Systems Safety Regulations 2000 inspection regime;
- Rileys, to draw up a list of outstanding works;
- NYMR, both because they were going to operate the locomotive and because there was a possibility of them becoming the owner;
- AEAT, because there was a possibility of the locomotive being run on the mainline railway.

31 With the overhaul complete, except for an agreed list of outstanding works, the locomotive returned to NYMR in November 2005. At around that time, ownership transferred from SPS jointly to NYMR and a private benefactor.

32 Throughout the time the locomotive was owned by SPS, the boiler was examined and certified by Boiler Inspector A. On the transfer of ownership, this role was transferred to Boiler Inspector B.

33 NYMR then completed any outstanding works themselves, requested an inspection from Boiler Inspector B, which was carried out, and put the locomotive back into service on 10 February 2006. It then completed 1194 miles (1910 km) prior to the blowback incident on 16 April 2006.

Figure 3: Locomotive 75029

Events preceding the accident

34 In mid March 2006, there were three reports logged relating to ash disturbances and air leaks in the locomotive smokebox. These were thought at the time to be the result of a poor seal between the saddle plate and the smokebox wall. These components are shown in Figure 6. In part as an attempt to cure this and to aid smokebox cleaning, the floor of the smokebox was lined in *refractory concrete* on 19 March.

35 On 14 April 2006, the joint between one of the blower feed pipes and the block at the smokebox wall, ie the opposite end from the joint to the blastpipe, was remade as a result of a leak.

36 On 15 April 2006, the locomotive was reported to be steaming poorly and had cracks in the refractory concrete. A decision was taken to run the locomotive for 48 hours until the *washout* scheduled for 17 April and then to investigate for any possible air leaks.

37 Early in the morning of 16 April 2006, the NYMR boilersmith, acting as the early turn fitter, noted that the locomotive had been booked for an ineffective blower by the crew the previous evening. The fitter checked the security of both blower feed pipes using a heeled bar and also used the residual boiler pressure to check that the blower valve operated correctly and that the nozzles on the front and rear blastpipe caps were clear, and recorded, 'No defect found'. The fitter noticed that there were signs of minor fracturing of the refractory concrete, completed the daily checks and started the fire.

38 Soon after 07:15 hrs, the crew of a driver, fireman and cleaner, prepared the locomotive. There were no indications of any problems with it, although contrary to NYMR training, their checks did not include opening the smokebox (although as they believed, it had been checked earlier by the fitter - paragraph 37 refers). They drove off the shed on time at 09:00 hrs.

39 They were required to perform some shunting before coupling to the 6-coach 09:45 hrs train waiting in platform 4 at Grosmont station. By the time the shunting was complete, the locomotive coupled to the train and the brakes tested, it was 10:00 hrs. The fireman had been building up the fire in anticipation of climbing the rising gradient ahead and as the train was ready to start, the boiler pressure was just under 220 psi (1.52 MPa).

40 The train departed the platform at 10:05 hrs, 20 minutes after the scheduled departure time. Once outside the 10 mph (16 km/h) speed restriction, the driver accelerated to gain speed for the climb. The train accelerated from 10 mph (16 km/h) to 20 mph (32 km/h) and started to climb the bank. The fireman completed applying a heavy round of coal in anticipation of the long climb and left the firebox door open. The regulator was fully open, the boiler pressure was 210 psi (1.45MPa), the *reverser* cut-off was 40 per cent and the blower was slightly open.

Events during the accident

41 The driver, aware that the train was late, wound the reverser cut-off out to between 50 and 60 per cent (further than he usually would for a six coach train), to try and maintain speed and make up time. At this time, the fireman was looking out of the right hand window facing the direction of travel and controlling the *injectors* and the cleaner was standing behind the fireman.

42 Within a few seconds of the cut-off being changed, the locomotive exhaust note *softened* and the driver, believing that the locomotive may have been *priming,* looked out of the left hand window to observe the locomotive's smoke. Smoke, which was described as normal black at the lower part, white above, was being emitted from both chimneys.

43 The cleaner then saw flames around 2.5 metres long engulfing a considerable area of the footplate in front of the firehole doors. The cleaner shouted a warning to the rest of the crew. The amount of flame and smoke was such as to make it impossible for the fireman to see across the footplate to the driver's side.

44 On hearing the warning, the driver turned back towards the footplate and saw the flames. The driver immediately shut the regulator, opened the blower and applied the train brake, the last action causing him to receive a minor burn to his right hand. The flames started to abate and the fireman was then able to kick the firehole doors shut finally stopping the blowback. By the time the train had stopped, the blowback had finished. The firehole doors and driver's controls are pictured in Figures 4 and 5.

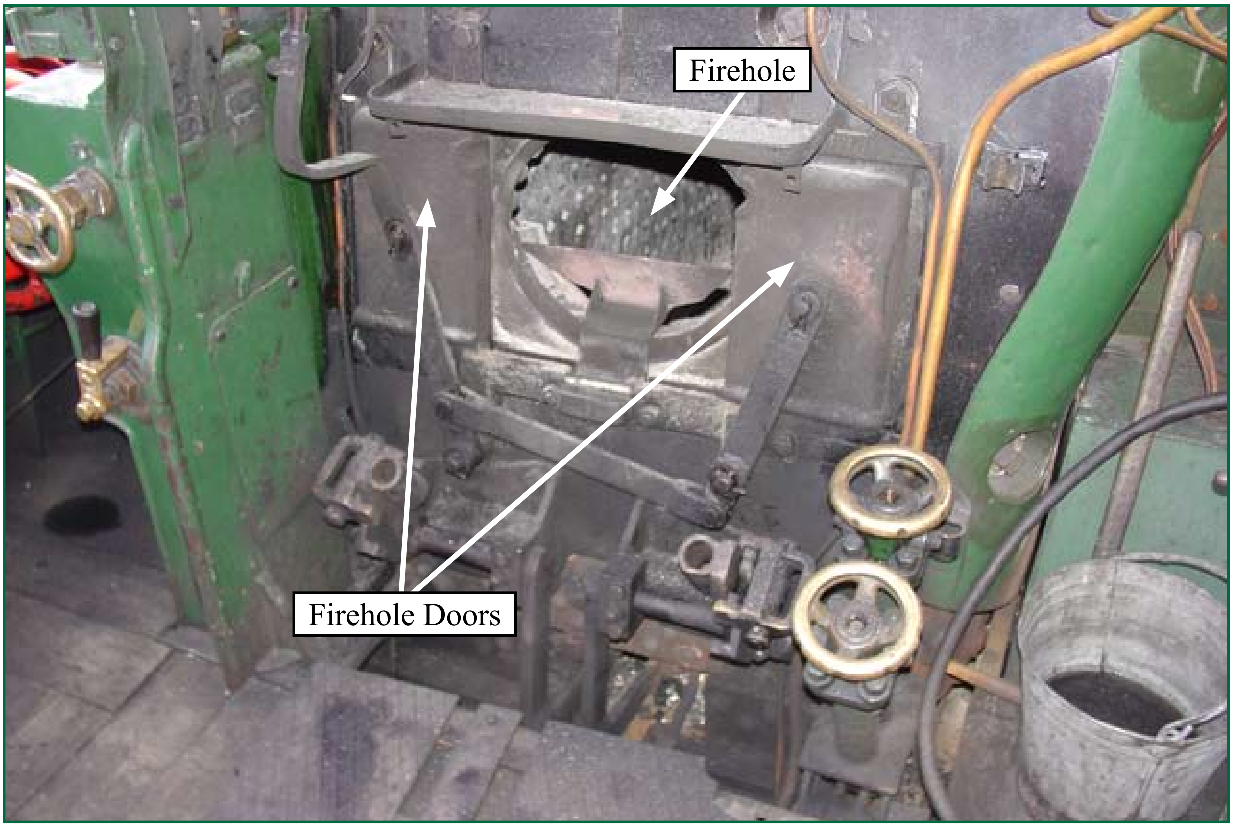


Figure 4: Locomotive 75029 footplate showing the firehole doors open

Consequences of the accident

45 As a result of the accident, the driver suffered minor burns to the right hand and right hand side of the face. No hospital treatment was required.

Events following the accident

46 Directly following the accident, the crew secured the train, put *protection* in place and made arrangements for the train to be towed back to Grosmont. They were assisted in this by members of NYMR staff who live in Esk Valley Cottages.

47 One of those staff noted that smoke was only coming from the front chimney of the locomotive. Another took the driver to a cottage to tend to his burned hand. There was no first aid box on the footplate of locomotive 75029. Further first aid was rendered to the driver later at Grosmont Station.

48 Once the train had been assisted to Grosmont station and the locomotive to the motive power depot (MPD), internal investigations into the cause of the accident commenced. The locomotive was examined for blocked *boiler tubes* and blown *superheater* elements, but none were found.

49 The refractory concrete in the smokebox showed obvious signs of breaking up and this led to a search for air leaks and the use of the reverser, with the locomotive stationary, to blow exhaust steam through the blastpipe. After a number of cycles, NYMR staff noted steam coming up through the cracks in the concrete around the bottom of the blastpipe. This provided them with evidence of an exhaust steam leak beneath the concrete.

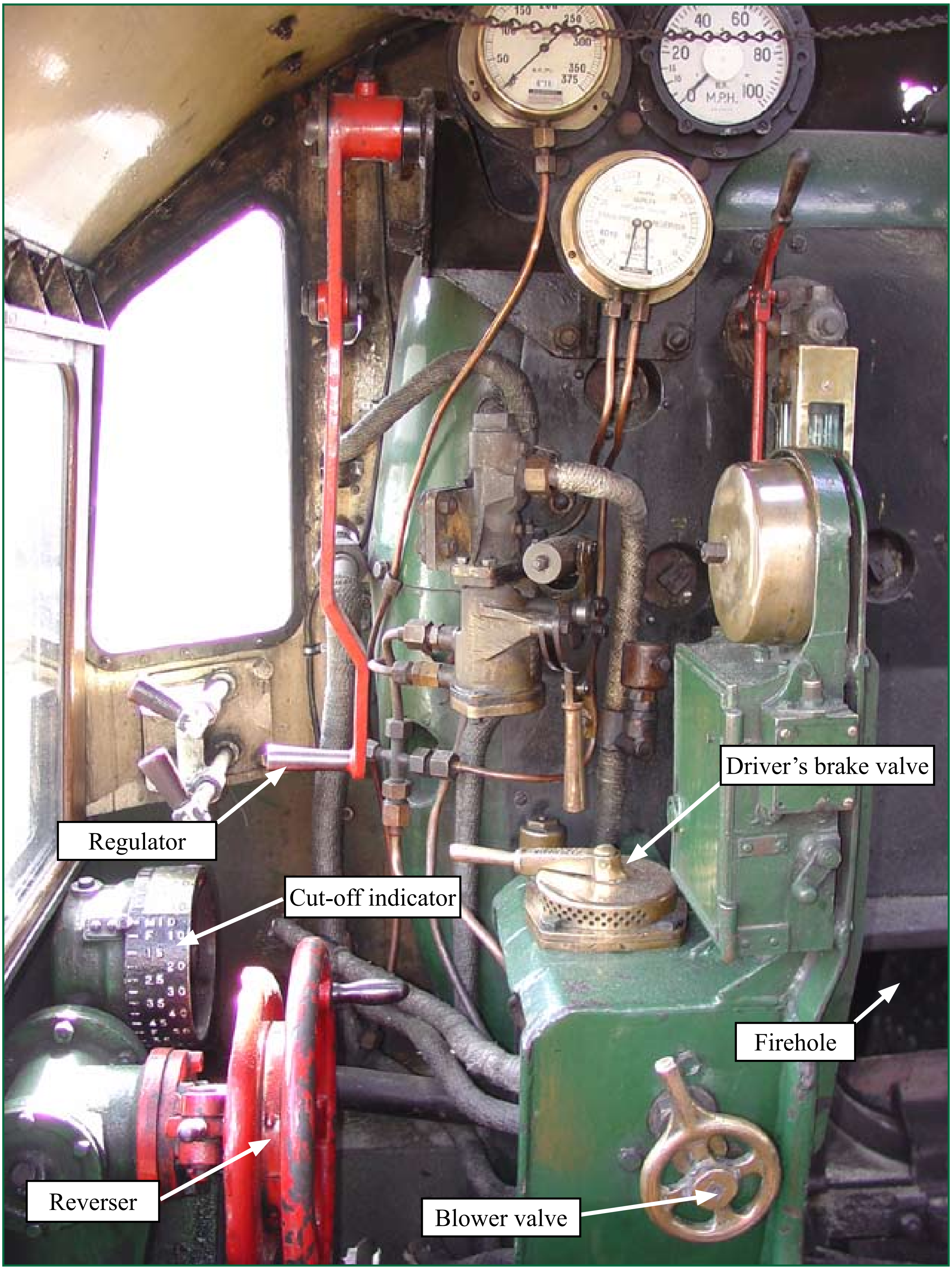


Figure 5: Locomotive 75029 footplate showing the driver's controls

50 They then found the drawings of the blastpipe and its base and concluded that a failure of the weld between the blastpipe base and the saddle plate was the most likely cause of the steam leak they were seeing, and of the blowback. NYMR called RAIB via the DfT Duty Office at 15:00 hrs on 16 April 2006. RAIB agreed that the locomotive would be left at Grosmont MPD until Monday 17 April, when they would attend on site.

51 On the morning of 17 April 2006, prior to RAIB arrival, NYMR staff went into the smokebox, and started to break out the refractory concrete. This action was contrary to the Railways (Accident Investigation and Reporting) Regulations 2005. At that time, they noticed that the rear blower feed pipe was fractured close to the flange.

52 On 18 April 2006, NYMR inspected their only other BR standard locomotive, 80135, and found that the same weld was heavily corroded and cracked.

53 On 18 April 2006, NYMR wrote to the BR Standard Locomotives Owners Group (BRSLOG) explaining the position with regard 75029 and 80135 and pointing out the potential for blowbacks to BRSLOG, with the view that this be shared with their members.

54 On the same day, NYMR wrote to AEAT explaining the weld failure on locomotive 75029, with a view that AEAT as a VAB would raise a National Incident Register (NIR) notification to cover all Standard classes certified to work on the mainline railway. Under the current system, AEAT are unable to raise NIRs themselves and requested West Coast Railways (West Coast) to do so. West Coast declined on the basis that the number of BR Standards operating on the mainline is very small and the owners are known; West Coast offered to provide contact details if necessary. In the end, no NIR was raised. RAIB accepted the attempt to have an NIR raised and notification of BRSLOG (paragraph 53 refers) as reasonable and sufficient initial actions by NYMR. Subsequently, RAIB contacted the Heritage Railway Association (HRA), established that they were unaware of the incident and requested NYMR to make them aware. NYMR did so and the HRA shared the information with their members.

The Investigation

Investigation process

55 As part of the investigation, the RAIB:

- examined the locomotive;
- conducted interviews;
- examined relevant documentation;
- surveyed the train's route;
- considered NYMR's own incident report;
- commissioned metallurgical examination of the blastpipe base weld and blower pipes by Serco Assurance Railtest.

56 Independent advice on the running and maintenance of steam locomotives was provided by Robert Meanley of Tyseley Locomotive Works, an experienced boiler designer and maintainer employed as a consultant by RAIB.

Key evidence

57 Witness and documentary evidence, and examination of the locomotive indicate that before the incident:

- during manufacture or since, an area of saddle plate adjacent to the blastpipe base was exposed to the smokebox environment because the smokebox plates were cut back and not butted up to the blastpipe base as shown on the drawing. As a consequence, the blastpipe base/saddle plate weld sits in a 'dirt trap' making it difficult to clean around and difficult to see (this is shown in Figure 6);
- there is no record to show that the blastpipe base/saddle plate weld has been intentionally broken and re-made over the previous 8 years;
- the NYMR maintenance regime is based around universal standards, particularly the 1984 BR standard, *MT/276 Examination Schedule for Preserved Steam Locomotives Running on BR Lines*, although the regime can be modified in light of experience;
- inspection of this weld was not part of the NYMR maintenance regime;
- no party involved in the recent overhaul or associated inspections specifically inspected the blastpipe base/saddle plate weld;
- responsibility for the inspection of mechanical parts of the locomotive during the recent overhaul at Rileys was not clearly defined;
- inspection of this weld by a Boiler Inspector is not required by the Pressure Systems Safety Regulations 2000, as the blastpipe is on the exhaust (low pressure) side of the cylinders;
- no one who had been otherwise involved with operating, inspecting or overhauling the locomotive over the last 8 years noticed the deteriorating weld and ensured that it was repaired;

- there was no detailed knowledge within NYMR or Rileys of the construction of the blastpipe base/saddle plate interface (the majority of British steam locomotives do not use the welded blastpipe base design);
- Boiler Inspector A has stated that whilst conducting a smoke box steam test on 4 October 2005 there was no leak around the blastpipe base when passing exhaust steam through the blastpipe with the locomotive stationary (Appendix D contains a schematic diagram showing gas flows in a steam locomotive);
- ash disturbances were noted in the smokebox on 11 March 2006 and 19 March 2006;
- the refractory concrete applied to the smokebox floor on 19 March 2006 showed signs of significant cracking by 16 April;
- the locomotive's performance had been variable in the days prior to 16 April 2006;
- on the morning of 16 April 2006, the blower feed pipes were secure, although it is possible that the rear pipe was cracked (paragraph 60, fifth bullet refers) and the blower functioned to a high degree.

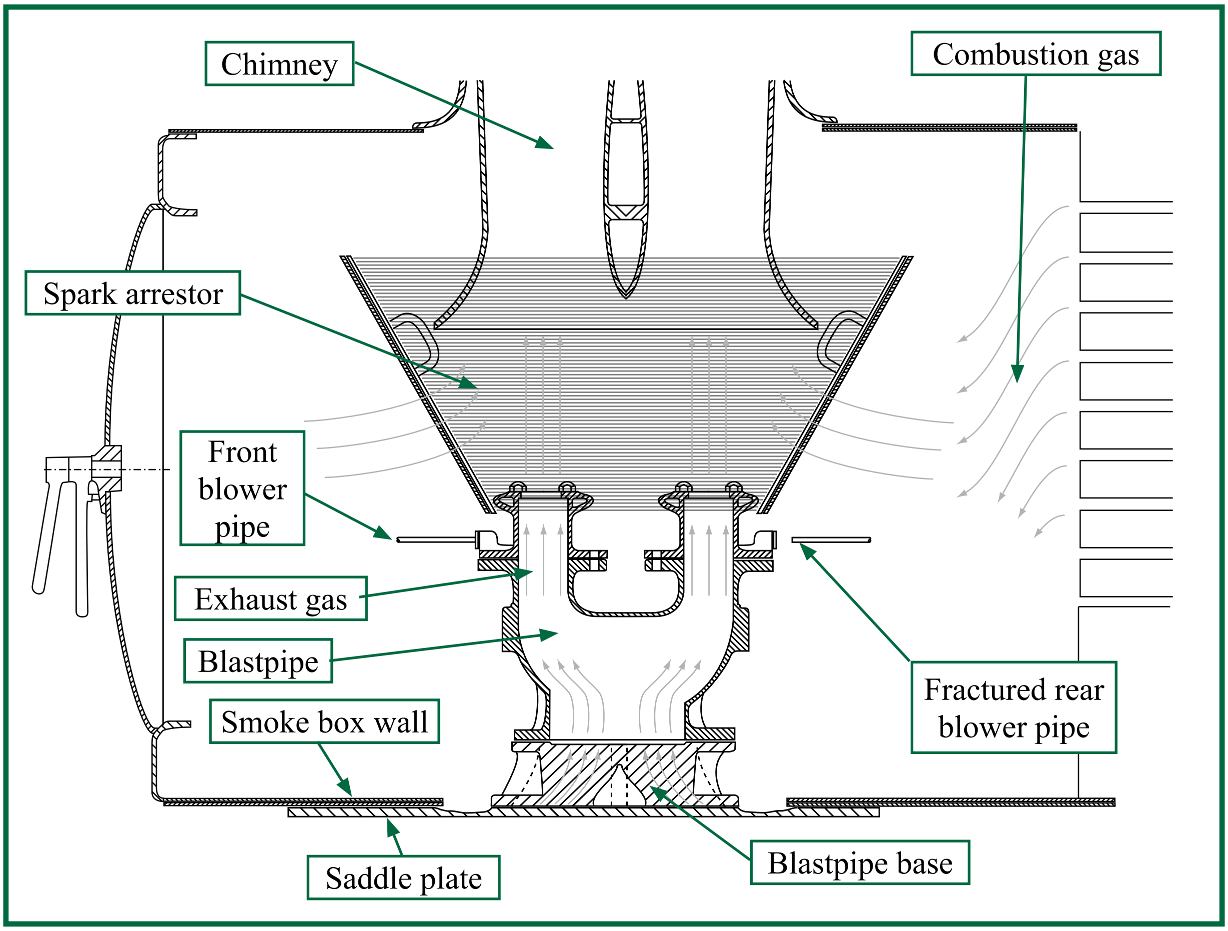


Figure 6: Simplified drawing of Locomotive 75029 blastpipe and associated smokebox components

58 Witness evidence and a time line derived from it indicate that during the incident:

- the movement of the reverser cut off point from 40 per cent to 50-60 per cent with full regulator was quickly followed by a softening of the exhaust note and then the blowback;
- once the exhaust note softened, observation of the exhaust by the driver indicated that the smoke was normal with a hint of black at the bottom, suggesting that the locomotive was not priming and the fire was not producing large quantities of black smoke;
- the flames blown back were around 2.5 metres long, directed upwards and slightly towards the driver (by the action of the wind direction);
- whilst accounts of which control was operated first conflict, the closely occurring actions of shutting of the regulator and full application of the blower caused the blowback to reduce;
- the blowback was finally stopped by the firehole door being kicked shut;
- the blowback is estimated to have lasted between 4 and 10 seconds.

59 Witness and documentary evidence, and examination of the locomotive indicate that after the incident:

- the blower worked to a degree, but only drew smoke through the front chimney;
- the boiler and superheater tubes were shown to be intact as no steam entered the firebox when the regulator was opened during testing;
- when exhaust steam was vented through the blastpipe during testing, some was seen to leak into the smokebox through the cracks in the concrete;
- the rear blower feed pipe was fractured (see Figure 7), but had only been fractured a relatively short time as evidenced by the bright surface observed on one fractured face on 17 April 2006 that had dulled significantly within ten days of the accident. This was confirmed by metallurgical examination (paragraph 60 refers);
- there was virtually no weld metal remaining between the blastpipe base and saddle plate and the remaining weld had failed (see Figure 9);
- the broken weld between blastpipe base and saddle plate was difficult to see clearly without cleaning the area with a wire brush and washing with solvent;
- the blastpipe was displaced around 5 mm to the left of its built position relative to the direction of travel;
- there were oily streaks on the bottom of the blastpipe base (see Figure 9);
- there were no obvious sources of air leakage into the smokebox.

Figure 7: The fractured rear blower feed pipe in-situ

Figure 8: The blastpipe in-situ

Figure 9: The underside of the blastpipe base

60 Metallurgical examination of samples indicate that:

- the weld between the blastpipe base and the saddle plate was unlikely to have been made to the design drawing – it was smaller than the 5/16 inch (8 mm) shown;
- through corrosion and/or erosion over a long period of time, the weld reduced to a point where only intermittent parts remained;
- the blastpipe base casting metal adjacent to the weld was brittle as a result of the welding process;
- the blastpipe base/saddle plate joint fractured a considerable time ago, several months or more probably years previously;
- the fracture of the rear blower feed pipe was propagated by fatigue, probably over a period of a few weeks, the final failure being by ductile overload;
- the blower feed pipes were not fully annealed over their lengths.

Previous occurrences of a similar character

61 Whilst blowbacks of steam locomotive fires are not uncommon, the RAIB has been unable to find any evidence of a blowback resulting from failure of a weld securing a blastpipe or a blastpipe/blastpipe base assembly to a saddle plate.

Analysis

Identification of the immediate cause

62 Witness evidence indicates that the incident was an explosive blowback. In this type of incident, volatile gases, which are being continuously produced from the hot firebed, momentarily cease to burn due to a lack of secondary air (oxygen) being drawn through the firehole door. These are trapped in the firebox and are then reignited by heat from the firebed, producing very rapid flame propagation, often entering the footplate.

63 The fireman had just applied a heavy round of coal, prior to the incident, which may have led to an increased rate of production of volatile gases. However, given the length of gradient being negotiated and the fact that this was the locomotive's first run of the day, there was nothing unusual or incorrect in the fireman's actions. Further, the chimney smoke was seen as normal by the driver, albeit with some black smoke at the bottom of the plume, suggesting nothing unduly amiss with the fire.

64 The fireman left the doors open to maximise the secondary air supply and again, given the way the locomotive was being worked, there was nothing unusual or incorrect in this. Texts on firing steam locomotives, including the The British Transport Commission (Railway Division) 'Good Firemanship' booklet, explains that depending on coal type and prevailing condition, the firehole doors may need to be left open to varying degrees.

65 As volatile gases were not being produced at a vastly excessive rate as evidenced by the exhaust smoke colour, and the fire box door was open, the lack of secondary air would have been a result of a loss of forward draught (from firebox to smokebox). Open fire box doors allowed the resulting explosive blowback to enter the footplate.

66 The immediate cause of the incident was therefore a loss of forward draught (from firebox to smokebox) at a time that the firehole doors were open.

Identification of causal and contributory factors

Discounted causal factors

67 There are a number of circumstances that can cause loss of forward draught which may result in a blowback. Most of these were discounted as described below:

- ruptured superheater elements or boiler tubes, discounted as there was no evidence of steam being blown into the firebox when opening the regulator after the incident;
- significant smokebox air leaks, discounted because none could be seen on examination of the smoke box;
- the effects of tunnels and cuttings, discounted as the incident occurred in open countryside on an embankment;
- inappropriate control of the regulator and blower, discounted because there is no evidence to suggest that the driver shut the regulator without opening the blower prior to the blowback.

68 The rear blower feed pipe was intact, although possibly cracked, when the locomotive left the shed that morning (paragraph 37 refers). Prior to the incident, the blower valve had been slightly open for a considerable time and during the incident opening the blower valve fully helped to reduce the flames. Immediately after the incident, the blower was drawing smoke through the front chimney only, suggesting that the rear blower pipe had fractured before then.

69 Calculations show that the steam pressure within the rear blower feed pipe, even if the blower valve was fully open, is insufficient to cause its final ductile overload failure (described in paragraph 60). Calculations also show that once the pipe had failed, it would not have displaced by much, either by the jetting action of leaking steam, when the blower was fully opened, or by the action of its own weight. Thus, any steam coming from the fractured blower pipe would have either been aimed at the flange or close to it. Marks on the flange and the clean fracture surface (see Figure 7) also suggest that steam was jetted in that direction after the pipe fractured. It is thus clear that steam jetting from the rear blower feed pipe would not have been aimed back at the *tubeplate*, which is another possible cause of blowbacks.

70 It is therefore concluded that the blower feed pipe most probably finally failed during the incident, as a result of blastpipe movement, at a time when the blower valve was slightly open. Whilst theoretically that may have resulted in a slight increase in smokebox pressure, this would have been negligable compared to the increase in pressure as a result of the blastpipe moving (paragraph 74 refers) and can therefore be discounted as a causal factor. This is further confirmed by the fact that when the blower valve was fully opened, it helped to reduce the blow back, rather than increase it.

Causal factors

71 After the incident, the blastpipe base was found not secured to the saddle plate and to have moved around 5 mm to the left relative to the direction of travel. Whether this movement was a direct result of the incident, the result of removing the refractory concrete with a bar by NYMR or by post incident vibration cannot be determined. However, what is clear is that the unsecured blastpipe/blastpipe base assembly could move relatively easily.

72 Post incident tests showed that at low exhaust pressure, steam leaked up through the cracked concrete close to the blastpipe base. Calculations show that at the kind of exhaust pressures developed with the control settings as they were at the onset of the incident, the blastpipe can be lifted by the passage of exhaust steam.

73 This, combined with the softening of exhaust note just after the reverser cut-off was wound out to 50 - 60 per cent and just prior to the blowback, indicates that the action of increased exhaust pressure caused the blastpipe to move and consequently the action of the blast in providing a forward draught for the fire was lost.

74 A factor is therefore that the movement of the blastpipe led to a loss of smoke box vacuum.

75 Whether the loss of vacuum was a result of angular movement of the blastpipe mis-aiming the exhaust jets and losing the *venturi effect*, or whether as a result of the lifting of the blastpipe base and the exhaust leakage from below, has not been determined. Either or both scenarios would have had a similar effect.

76 Metallurgical examination indicated that the blastpipe base/saddle plate weld had failed some considerable time previously and that the blower feed pipe had fatigued rapidly, quite possibly as a consequence of increased movements of an unsecured blastpipe. Further evidence that the blastpipe had been unsecured for some time is provided by the oil streaking on the underside of the blastpipe base, which suggests that oily exhaust steam had been escaping for some time.

77 Thus, the movement of the blastpipe was primarily a result of the locomotive operating with a failed blastpipe/saddle plate weld, which in turn was a result of the weld having failed some time previously and the failed weld not being noticed and repaired.

78 It has not been possible to determine exactly when the weld finally failed completely. Metallurgical examination indicates that the failure occurred months or even years prior to the incident. On 4 October 2005, tests by Boiler Inspector A showed no leak around the blastpipe base with low pressure exhaust. Similar tests after the incident, did reveal leaks. It must also be the case that the attachment of the base to the saddle plate must have been sufficient to restrain the base when the blastpipe was last bolted down during the overhaul at Rileys, which suggests that some attachment was still left at that time. However, the timing of the weld failure is not critical because the weld would have corroded over years prior to complete failure and its condition could therefore have been noticed and repaired prior to the incident, either before or after it had failed completely.

Contributory factors to the movement of the blastpipe.

79 The blastpipe's movement was primarily because the base was not secured to the saddleplate, however, the fact that the blastpipe movement was large enough on this occasion, to result in a significant blowback, suggests that there were other factors contributing.

80 The exhaust note softened very soon after the reverser cut-off was wound out. It is therefore concluded that the high exhaust pressure as a result of the control positions at the time was a contributory factor.

81 Whilst the driver was working the locomotive hard to make up time on the uphill climb, there is nothing in his actions that is unusual or incorrect.

82 A possible contributory factor is the cracking concrete providing reduced restraint of the blastpipe base. As the restraint of components is not the intended function of refractory concrete, this possible contributory factor is not considered further.

Contributory factors to the failed weld

83 The blastpipe base/saddle plate weld had failed prior to the incident because of a combination of the likelihood of the weld being made undersized and it being subject to long-term corrosion and erosion. Both these factors are contributory.

84 The weld being made undersized relative to drawings is a construction issue and may well originate in the 1950s in this case.

85 The fact that the weld had been subject to long term corrosion is in the nature of the smokebox environment.

Common contributory factors to the failed weld and it not being noticed and repaired

86 There are five contributory factors that are common to the blastpipe base/saddle plate weld having corroded and failed, and to the fact that the failed weld had had not been noticed and repaired.

87 The condition of the weld was not easy to see, even when not covered in concrete. This is in the nature of the smokebox construction.

88 No party involved in the recent overhaul or associated inspections specifically inspected the blastpipe base/saddle plate weld.

89 There was no requirement for any party involved in the recent overhaul and associated inspections to inspect the blastpipe base/saddle plate weld.

90 Indicative signs prior to the incident did not lead to an examination of the blastpipe base/saddle plate weld by NYMR.

91 The NYMR maintenance regime did not call for periodic inspection of the blastpipe base/saddle plate weld.

Underlying causes

92 The risk associated with the blastpipe base/saddle plate weld was not generally appreciated because such an incident had not occurred before and there was no detailed understanding of the construction of the blastpipe base/saddle plate interface.

93 NYMR maintains locomotives to procedures derived from universal BR steam locomotive standards, with the experience of problems causing maintenance procedures to be modified. This means that a specific risk associated with a specific locomotive type that has not been known to have occurred previously, may not be controlled.

Severity of consequences

94 The driver of the locomotive suffered minor burns to the right hand and right hand side of the face.

95 The incident had the potential to have resulted in much more severe consequences, had anyone been standing in line with the firehole door.

Summary of the event chain

96 The diagram shown in Figure 10 illustrates the causal, contributory and underlying factors graphically.

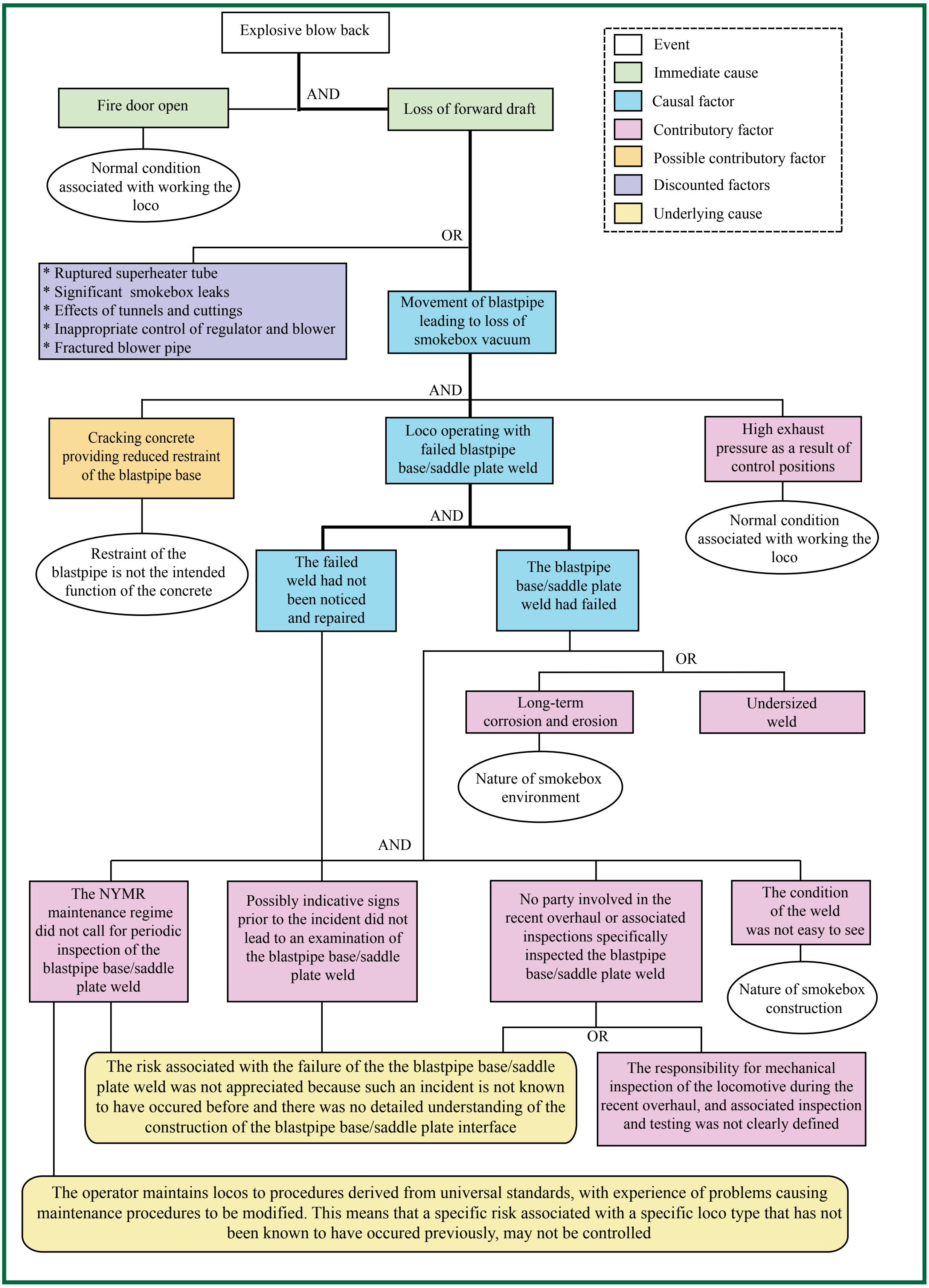


Figure 10: Diagram showing chain of events and factors

Conclusions

Immediate cause

97 The immediate cause of the accident was a loss of forward draught (from firebox to smokebox) at a time that the firehole doors were open.

Causal and contributory factors

98 The following causal factors were identified:

- the movement of the blastpipe leading to a loss of smokebox vacuum;
- the locomotive was operating with a blastpipe base/saddle plate weld that had failed some time previously and had not been noticed and repaired (Recommendation 1).

99 In addition, the following factors were considered to be contributory:

- high exhaust pressure as a result of the control positions;
- the blastpipe base/saddle plate weld was likely to have been made undersized relative to the design drawing (Recommendation 2);
- the blastpipe base/saddleplate weld was subject to long-term corrosion and erosion;
- the condition of the weld was not easy to see;
- no party involved in the recent overhaul or associated inspections specifically inspected the blastpipe base/ saddle plate weld;
- the responsibility for mechanical inspection of the locomotive during the recent overhaul, and associated inspection and testing was not clearly defined (Recommendation 3);
- indicative signs prior to the incident did not lead to an examination of the blastpipe base/saddle plate weld by NYMR;
- the NYMR maintenance regime did not call for periodic inspection of the blastpipe base/ saddle plate weld (Recommendation 4).

100 The following underlying causes were identified:

- the risk associated with the failure of blastpipe base/saddle plate weld was not generally appreciated because such an incident had not occurred before and there was no detailed understanding of the construction of the blastpipe base/saddle plate interface;
- NYMR maintains locomotives to procedures derived from universal BR steam locomotive standards, with problems experienced causing maintenance procedures to be modified. This means that a specific risk associated with a specific locomotive type that has not been known to have occurred previously, may not be controlled (Recommendations 5 and 6).

Other factors affecting the consequences

101 The relatively minor consequence of the blowback was a result of the crew being fortuitously positioned away from the firehole door.

Additional observations

102 There was no first aid box on the locomotive footplate as recommended by HMRI Railway Safety Principles and Guidance Part 2, Section H Minor Railways, Paragraph 411 (Recommendation 7).

103 NYMR chose to fit copper, rather than steel, blower feed pipes on the basis of their own LNER based practice. However, the copper pipes were not fully annealed over their length as recommended in HS(G) 29, The Management of Steam Locomotive Boilers (Recommendation 8).

104 There is no formal means of quickly disseminating applicable information about incidents between the heritage sector and the mainline railway. This is the case whichever is the direction of information flow. The HRA receive applicable NIRs from the mainline railway on an informal basis and this is understood to be effective on the majority of cases. They then disseminate this to the heritage railways via the Operating and Safety Committee. Conversely, heritage railways may try to have NIRs raised to pass information to the mainline railway, but again by informal means. In relation to this incident however, no NIR was raised despite NYMR's efforts (Recommendation 9).

Actions reported as already taken or in progress relevant to this report

105 NYMR have repaired locomotive 75029 with weld larger than 5/16 inch (8 mm) and have checked the weld quality with *non-destructive testing* (NDT).

106 On 18 April 2006, they inspected their only other BR standard locomotive 80135 and found that the same weld was heavily corroded and cracked. A similar repair was undertaken.

107 On 18 April 2006, NYMR wrote to the BR Standard Locomotives Owners Group (BRSLOG) explaining the position with regard 75029 and 80135 and pointing out the potential for blowbacks to BRSLOG, with the view that this be shared with their members. BRSLOG have done this and to date, no one has reported problems with blastpipe/saddle plate welds on their BR Standard class locomotives.

108 On the same day, NYMR wrote to AEAT explaining the weld failure on 75029, with a view that AEAT as a VAB would raise an NIR to cover all Standard classes certified to work on the mainline railway. Under the current system AEAT are unable to raise NIRs themselves and requested West Coast Railways to do so. West Coast declined on the basis that the number of BR Standards operating on the mainline is very small and the owners are known; they offered to provide contact details if necessary.

109 NYMR are in the process of amending their maintenance regime to include a 5 yearly NDT of the blastpipe base/saddle plate weld on their BR Standard class locomotives.

110 HMRI and HRA are currently developing a Code of Practice for the Maintenance and Repair of Steam Locomotive Boilers and intend to include a recommendation that the assessment of hazards be undertaken by steam locomotive operators to underpin their maintenance regimes.

111 NYMR have re-briefed their staff on the reporting and evidence protection requirements of the Railways (Accident Investigation and Reporting) Regulations 2005.

Recommendations

112 The following safety recommendations are made:[1]

Recommendations to address causal and contributory factors

1 NYMR and other operators of locomotives with blastpipes or blastpipe bases welded to the saddle plate, should carry out an immediate, where reasonably practicable, and appropriate NDT examination of the blastpipe base/saddle plate weld and, where necessary, make suitable repairs (paragraph 98).

2 HMRI and HRA should ensure that the forthcoming Code of Practice on the Maintenance and Repair of Locomotive Boilers provides guidance to those repairing existing welded blastpipe bases or constructing such designs from drawings. This should recommend that welds between blastpipe bases and saddle plates should, as a minimum, be sized as shown in the original drawings and that in sizing the weld, consideration should be given to the subsequent inspection periodicity, the arrangement of the adjacent plating and any intention to line the smoke box base with concrete or fire-brick (paragraph 99).

3 Steam Powered Services Limited should have in place procedures to ensure that when defining and agreeing outsourced works to be carried out, the scope of any provision for mechanical inspections is explicitly defined (paragraph 99).

4 NYMR and other operators of locomotives fitted with blastpipes or blastpipe bases welded to the saddle plate, should ensure that the maintenance procedures for those locomotives include NDT inspection of the welds at a periodicity determined by assessing the risk of failure prior to the next inspection (paragraph 99).

5 When developing maintenance and overhaul schedules, NYMR should assess the hazards to operating staff and the public that the specific design of locomotive concerned presents, and develop the schedules to account for those hazards (paragraph 100).

6 HMRI and HRA should assess the applicability of Recommendation 5 to other steam locomotive operators and, if it is more widely applicable, incorporate the recommendation within the forthcoming Code of Practice for the Maintenance and Repair of Steam Locomotive Boilers and any other standards or guidance they issue on steam locomotive maintenance (paragraph 100).

continued

[1] Responsibilities in respect to these recommendations are set out in the Railways (Accident Investigation and Reporting) Regulations 2005 and the accompanying guidance notes, which can be found on the RAIB web site at www.raib.gov.uk

Recommendations to address other matters observed during the investigation

7 NYMR should ensure that a first-aid kit is provided and its provision clearly indicated in all locomotive driving cabs (paragraph 102).

8 NYMR should use steel smoke box blower feed pipes as recommended by HMRI RSPG or, if copper is to be used, should put in place procedures to ensure that it is maintained in a fully annealed state (paragraph 103).

9 RSSB should allow the HRA direct access to the NIR system, both to raise NIRs and receive them (paragraph 104).

Appendices

Glossary of abbreviations and acronyms — Appendix A

AEAT	AEA Technology Limited
BR	British Railways
BRSLOG	British Railways Standard Locomotive Owners Group
GCR	Great Central Railway
HMRI	Her Majesty's Railway Inspectorate
HRA	Heritage Railway Association
LNER	London and North Eastern Railway
NDT	Non-destructive testing
NIR	National Incident Register
NYMR	North Yorkshire Moors Railway
MPD	Motive Power (locomotive) Depot
SPS	Steam Powered Services Limited
VAB	Vehicle Acceptance Body

Glossary of terms **Appendix B**

Blastpipe	A pipe within the smokebox to direct exhaust steam into the chimney in a manner that also draws combustion gases out of the smokebox and into the chimney.
Blower feed pipes	Pipes feeding steam to the blower rings located around the blastpipe caps. This steam is used to draw combustion gases out of the smoke box and into the chimney when there is no exhaust steam.
Boiler ticket	Colloquial term for the period of time elapsing from one statutory hydraulic boiler test to the next, usually considered to be 10 years. However, all boilers are required to be thoroughly examined every 12 months, at which point the boiler's condition may necessitate removal from service.
Boiler tubes	Usually steam tubes which carry combustion gases from the firebox to the smokebox and which provide an additional heating surface for the boiler.
Firebox	Part of the boiler that contains the fire. It is surrounded by water that the fire heats to generate steam.
Firehole door	Opening at the back of the boiler to permit placing coal on the fire, admittance of secondary air (to allow the volatile gases in the top of the firebox to be burnt) and for inspection access when the locomotive is cold.
Footplate	The area enclosed by the locomotive cab provided to house the crew.
Injectors	Item of equipment for feeding water into the boiler under pressure by the use of steam jet principles.
MT/276 Examination Schedule for Preserved Steam Locomotives Running on BR Lines	A standard issued by British Railways in 1984 detailing the examinations steam locomotives were required to undergo before and whilst being allowed to run on British Railways infrastructure. It is called up in current Rail Group Standards and thus applies to locomotives allowed to run on Network Rail infrastructure. Heritage Rail operators may choose to apply the standard to locomotives that do not run on Network Rail infrastructure.
Non-destructive testing	Testing the integrity of materials, especially those made from metals, to confirm their fitness for continuing service without damaging or destroying the item being tested. Examples include dye-penetrant inspection, magnetic particle inspection, x-ray inspection and ultrasonic flaw detection.
Priming	The entrainment of boiler water with steam being drawn from the boiler. This may be caused by too high a water level, or high levels of solids or contaminants in the water.
Protection	In this case, the placing of detonators on the line to stop other trains from entering the area in which the failed train was standing.
Refractory concrete	Concrete capable of withstanding high temperatures.

Reverser	A driver's control which adjusts the locomotive's valve-gear to achieve forward or reverse operation and to control the amount of steam admitted to the cylinder during each stroke.
Rileys	Riley & Sons (Electromec) Limited – locomotive owners, maintainers and repairers.
Saddle plate	Part of a fabrication bolted to the front of the locomotive frame which forms a seating and support for the smokebox and front end of the boiler.
Smokebox	An enclosure at the front of the boiler from where combustion gases are draw through the boiler tubes and up the chimney by the action of exhaust and/or blower steam through the blastpipe.
Softened	The change of exhaust note from a distinct sharp pulses to flatter, less distinct pulses.
Superheater	Arrangement of steam tubes within a boiler flue to add extra heat to the steam being fed to the cylinders. It is fitted to increase power and efficiency.
Tubeplate	End plates at the front and back of the boiler that hold the boiler tubes in place.
Vehicle Acceptance Body	An inspection authority accredited, by the Rail Safety and Standards Board on behalf of Network Rail, to certify that rolling stock meets the applicable standards before it can be run on Network Rail infrastructure.
Venturi effect	The reduction in pressure associated with a fast flowing liquid or gas.
Washout	A process of removing plugs and doors to enable mud, sludge and scale to be washed out of a boiler with water jets. It is usually combined with periodic inspection by the operator and the frequency is determined by policy, water quality and locomotive usage.

Key standards current at the time **Appendix C**

HMRI Railway Safety Principles and Guidance Part 2, Section H	Minor Railways
HS(G) 29	The Management of Steam Locomotive Boilers
MT/276	Examination Schedule for Preserved Steam Locomotives Running on BR Lines
Statutory Instrument 2000 No. 128	Pressure Systems Safety Regulations 2000

Primary air - Primary air drawn through a grate under the fire provides oxygen for the coal to burn.

Secondary air - Secondary air drawn through the firehole door provides oxygen for the volotile gases, above the hot coal, to burn.

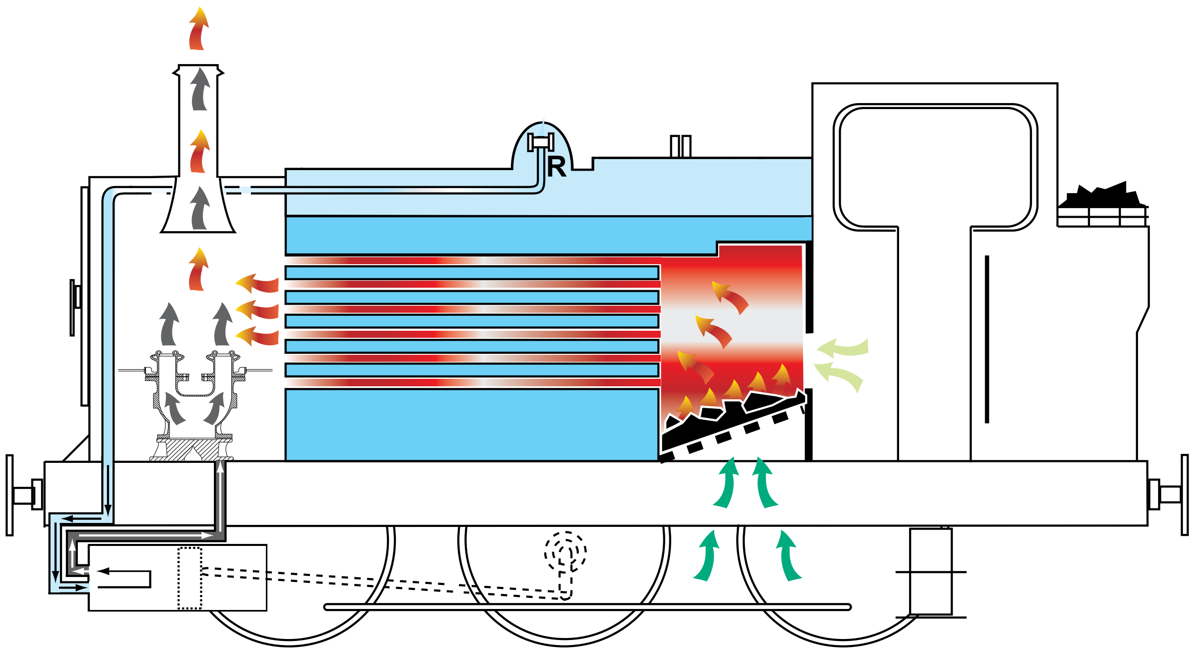
Combustion Gas - Hot combustion gases are drawn through the boiler tubes, heating the water surrounding the tubes and firebox.

Water.

High pressure steam - High pressure steam passes through the regulator valve **R** (when open) and is fed to the cylinders to drive the wheels.

Exhaust Steam - Exhaust steam from the cylinders passes up through the blast pipe and reduces the pressure in the smoke box, drawing the combustion gases through the boiler.

* if the regulator valve is closed and there is no exhaust steam passing through the blast pipe, the driver can still draw the combustion gases through the boiler tubes by artificially injecting high pressure steam from the boiler in to the blast pipe. The steam is injected through the blower.



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